CLAIMS

1. A method of monitoring the presence of one or more chromophores in a sample of biological tissue, which method comprises
illuminating an area of such tissue sample by projecting light from a light source,
receiving light remitted by the illuminated area of tissue at a photo-receptor, spectroscopically analyzing the remitted light,
and comparing variations in the intensity and spectral characteristics of the remitted light with respect to the intensity and spectral characteristics of the projected light and with data representing a datum sample of intensity and spectral characteristics, and emitting a control signal in response to any such variations.

2. A method according to Claim 1, wherein said datum sample represents the intensity and spectral characteristics of light remitted by a sample of epithelial or epithelial and sub-epithelial tissue.

3. A method according to claim 2, wherein said datum sample represents the intensity and spectral characteristics of light remitted by a sample of skin.

4. A method according to claim 1, wherein said datum sample represents the intensity and spectral characteristics of light remitted by a sample of tissue of known structure.

5. A method according to claim 4 of deriving data relating to the presence and/or depth and/or concentration of any chromophore selected from the group consisting of: melanin, blood, haemoglobin, oxy-haemoglobin, bilirubin, tattoo pigments and dyestuffs, keratin, collagen and hair.

6. A method according to claim 1, wherein said datum sample represents the intensity and spectral characteristics of remitted light as calculated from a mathematical optical model of the tissue.

7. A method according to claim 6 of deriving data relating to the presence and/or depth and/or concentration of any chromophore selected from the group consisting of: melanin, blood, haemoglobin, oxy-haemoglobin, bilirubin, tattoo pigments and dyestuffs, keratin, collagen and hair.

8. A method according to claim 1 applied for non-invasive monitoring of the presence of one or more said chromophores in the tissue sample.

9. A method according to claim 8 applied for controlling a treatment which involves the irradiation of a region of tissue with treatment light of predetermined spectral characteristics, wherein the absorption characteristics of tissue supervening the region to be treated for the treatment light are measured and used in calculating a required exposure of the tissue to the treatment light.

10. A method according to claim 8 applied for predicting the outcome of a treatment which involves the irradiation of a region of tissue with treatment light of predetermined spectral characteristics, wherein the absorption characteristics for the treatment light of the tissue region to be treated and of tissue supervening the region to be treated are measured and used in calculating a required therapeutically effective exposure of the tissue to the treatment light, and the required exposure and the absorption characteristics of the supervening tissue are used to predict potential destruction or scarring of the supervening tissue by such exposure.

11. A method according to claim 4 applied for endoscopic monitoring of the presence of one or more said chromophores in the tissue sample.

12. A method according to claim 6 applied for endoscopic monitoring of the presence of one or more said chromophores in the tissue sample.

13. A method of non-invasively analyzing tissue structure, comprising the steps of:

(i) measuring red or infrared radiation from at least one location in an area of tissue under investigation so as to give an indication of any layered structure in said area;

(ii) measuring the tissue color co-ordinates at said at least one location in said area of tissue;

(iii) using data obtained in measuring steps (i) and (ii) to calculate corrected tissue color co-ordinates in respect of said area which corresponds to a predetermined thickness of said layered structure, and;

(iv) comparing the corrected tissue color co-ordinates obtained in step (iii) with a reference color co-ordinate range for healthy tissue having a layered structure of the same predetermined thickness.

14. A method according to claim 13, wherein said layered structure comprises a layer of collagen.

15. A method according to claim 13 where the light in section (i) extends across the UV and/or visible and/or IR regions.

16. A method according to claim 13, comprising the additional step of;

(v) identifying corrected tissue color co-ordinates which lie outside the reference color co-ordinate range.

17. A method according to claim 16, comprising the additional steps of;

(vi) comparing the degree of deviation of the corrected tissue color co-ordinates which lie outside the reference color co-ordinate range with generalized levels of deviation from a reference color co-ordinate range known to be associated with differing abnormalities in said tissue, and;

(vii) using the tissue color co-ordinates to assess the degree of abnormality of said tissue.

18. A method according to claim 13, comprising of additional steps of (vi) calibrating the corrected tissue color co-ordinates with the corrected tissue co-ordinates of at least one tissue location having color co-ordinates lying within said reference color co-ordinate range for normal tissue;
(vii) using the tissue color co-ordinates to assess the degree of abnormality of said tissue.

19. A method according to claim 13, wherein an independent measurement of the level of epidermal melanin is made.

20. A method according to claim 18, wherein said calibration in step (vi) includes estimating the level of epidermal melanin at said location by reference to epidermal melanin levels calculated within at least one normal skin region adjacent said location.

21. A method according to claim 17, wherein said calibration in step (vi) includes measuring epidermal melanin levels at said location by assessing the deviation at the blue end of the spectrum at said location from the reference color co-ordinate range for normal skin.

22. A method according to claim 16, wherein the tissue color co-ordinates at said at least one location in said area of tissue are measured in a manner which is blind to the presence of melanin.

23. A method according to claim 16 where the properties of polarized light are used to remove the effects of epidermal melanin.

24. A method according to claim 13, wherein in step (i), a single infrared image at a wavelength of greater than about 1100 nm is obtained for the or each said location.

25. A method according to claim 16, wherein in step (i) two red or infrared images. each at a different wavelength, are obtained for each of said locations, whereby to enable the effect of the presence of epidermal melanin and dermal blood and collagen to be accounted for in the calculation of step (iii).

26. A method according to claim 16, wherein in step (i) two infrared images, each at a different wavelength, are obtained for each of said locations, thereby to enable the effect of the presence of epidermal melanin and dermal blood to be accounted for in the calculation of step (iii).

27. A method according to claim 25, wherein said infrared image(s) is/are obtained using infrared photographic film, or laser(s)or by spectral analysis.

28. A method according to claim 13, wherein the reference color co-ordinate range for normal tissue at the predetermined collagen layer thickness referred to in step (iv) is obtained as a curved surface lying within a three-dimensional color space, with a first bounding axis relating to the amount of a first chromophore within the collagen layer and a second bounding axis relating to the amount of a second chromophore within the collagen layer.

29. A method according to claim 28, wherein said collagen layer is the papillary dermis, said first chromophore is epidermal melanin and said second chromophore is blood.

30. A method according to claim 28, wherein said three-dimensional color space is selected from LMS, RGB and UV G IR color spaces.

31. A method according to claim 13, wherein the skin color co-ordinates of step (ii) are acquired from an image using the same lighting conditions and the same calibration set-up as used to produce the healthy skin reference color co-ordinate range.

32. A method according to claim 13, wherein the skin color co-ordinates of step (ii) are acquired from an image using different lighting conditions than used to obtain the healthy skin reference color co-ordinate range, and a white standard or other correction factor is used to allow calibration of the image with the reference color co-ordinate range.

33. A method according to claim 13 of deriving data relating to the presence, depth, and concentration of chromophores and creating and displaying a map thereof.

34. A method of mapping the papillary surface of an area of the dermis which comprises illuminating the surface of the skin over that area with light and monitoring the intensity of the light remitted from along at least one line or sequence of points, the light having a wavelength sufficiently far into the infra-red that its absorption by melanin and blood is negligible, or having at least two wavelengths of which at least one is in excess of 600nm and deriving therefrom a theoretical intensity of remitted light which is independent of the presence of melanin or blood, and from the remitted light intensity deriving a signal corresponding to the concentration of collagen within the papillary dermis along the or each line or at each point, and producing a contoured image in which the apparent elevation of any point is dependent upon the strength of such signal.

35. Apparatus for monitoring the presence of one or more chromophores in a biological tissue sample, which apparatus comprises

a light source for projecting light to illuminate an area of such tissue sample,

a photo-receptor for receiving light remitted by the illuminated area of tissue, and a spectroscopic analyzer for monitoring the remitted light,

a comparator for comparing variations in the intensity and spectral characteristics of the remitted light with respect to the intensity and spectral characteristics of the projected light at different wavelengths and

with data representing a datum sample of intensity and spectral characteristics of light and a signal emitter for emitting a control signal in response to any such variations.

36. Apparatus according to claim 35, wherein said record is a record of the intensity and spectral characteristics of light remitted by a reference sample of epithelial or epithelial and sub-epithelial tissue.

37. Apparatus according to claim 36, wherein said record is a record of the intensity and spectral characteristics of light remitted by a reference sample of skin.

38. Apparatus according to claim 35, wherein said record is a record of the intensity and spectral characteristics of light remitted by a reference sample of normal healthy tissue.

39. Apparatus according to claim 35, wherein a set of filters is provided for selective substitution into the tissue-incident light path in order to effect measurements at different wavelengths.

40. Apparatus according to claim 35, wherein means is provided for polarizing the light which illuminates said area of tissue.

41. Apparatus according to claim 40, wherein a cross-polarized filter is provided in the path of such polarized light remitted from said area of tissue before it is received by said photo-receptor.

42. Apparatus according to claim 35, wherein means is provided for passing a said control signal to one or more of the following: a display device such as a display monitor, a printer, or a medical laser or other treatment device or apparatus.

43. Apparatus according to claim 35, wherein means is provided for illuminating said area of tissue with light having a wavelength in excess of 600nm.

44. Apparatus according to claim 43, wherein means is provided for monitoring light of wavelengths in the 800 to 1000 nm band and the 600 to 800 nm band.

45. Apparatus according to claim 35, wherein said light source, photo-receptor and spectroscopic analyzer means are together adapted to give a result which is blind to the effects of melanin.

46. Apparatus according to claim 35, wherein means is provided for monitoring the intensity of the light remitted from a plurality of lines or a two-dimensional array of points.

47. Apparatus according to claim 35, wherein means is provided for monitoring the intensity of the light remitted with a resolution of at least 20 lines or dots per mm.

48. Apparatus according to claim 36, wherein an image of remitted light is captured using a digital camera in which use is made of a charge coupled device measuring 20×15 mm or less with a resolution of 800×600 pixels or more.

49. Apparatus according to claim 35, wherein a light guide of which at least part is flexible is provided for conducting light between said source, said tissue sample and said photo-receptor.

50. Apparatus according to Claim 49, wherein said light guide comprises an endoscope.

51. Apparatus according to Claim 49, wherein said light guide terminates in a head adapted for placing against an area of skin.

52. Apparatus according to claim 35, wherein means is provided for varying the size of the area of tissue monitored.

53. Apparatus for non-invasively analyzing skin structure, comprising:
means for projecting UV and/or visible and/or red and/or infrared radiation onto an area of skin under investigation,
measuring means for measuring remitted red or infrared radiation from at least one location over said area of skin so as to give an indication of the collagen thickness in said area;
skin color co-ordinate measuring means for measuring the skin color co-ordinates at said at least one location in said area of skin;
calculating means for using data obtained in measuring steps (i) and (ii) to calculate corrected skin color co-ordinates in respect of the or at least one said area which corresponds to a predetermined amount of collagen, and;
color comparison means for comparing the corrected skin color co-ordinates obtained in step (iii) with a reference color co-ordinate range for skin with the same collagen content.

54. Apparatus for mapping the papillary surface of an area of the dermis which comprises a light source illuminating the surface of the skin over that area with light which either has a wavelength sufficiently far into the infra-red that its absorption by melanin and blood is negligible, or which has at least two wavelengths of which at least one is in excess of 600 nm, means for monitoring the intensity of the light remitted along at least one line or sequence of points, and deriving therefrom an intensity or theoretical intensity of remitted light which is independent of the presence of melanin or blood, and means for deriving a signal from the remitted light intensity corresponding to the concentration of collagen within the papillary dermis along the or each line or at each point, and for producing a contoured image in which the apparent elevation of any point is dependent upon the strength of such signal.

55. Use of apparatus according to claim 35 for deriving data relating to the presence, depth, and concentration of chromophores and creating and displaying a map thereof.

56. Use of apparatus according to claim 35 for deriving data relating to the presence, depth, and concentration of any chromophore selected from the group consisting of: melanin, blood, haemoglobin, oxy-haemoglobin, bilirubin, tattoo pigments or dyestuffs, keratin, collagen and hair.

57. Use of apparatus according to claim 35 for mapping the extent of a basal cell carcinoma.

58. A method of analyzing biological tissue comprising illuminating the tissue with light, spectrally measuring and analyzing the differences between the incident and remitted light, the analysis of this data to define a parameter of the tissue, the normalization of the data to a standard value of that parameter using a predictive mathematical model of the optical properties of the biological tissue, and the subsequent measurement of a further parameter from that normalized data.

59. A method according to claim 58 but with more than one sequential normalization and analysis step to define further parameters.

60. A method for analyzing biological tissue comprising the illumination of the tissue with light, the spectral measurement of the differences between the incident and remitted light, the analysis of these data by comparison of features present within these data with a previous mapping of these features to components or structures present in the tissue.

61. A method according to claim 60 whereby the previous mapping of features is achieved by measuring samples of tissue experimentally.

62. A method according to claim 60 but with the mapping between features of the data and components or structures in the tissue taking the form of a multi dimensional table, with a dimension for each measurable component or structure.

63. A method according to claim 62 wherein a feature of the spectral data is used to select a sub set of these tables, and one or more features are subsequently used to select further sub sets of tables relating to components or structures within the tissue.